Autonomous Sensing of Layered Structures in Hawaiian Waters

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LONG-TERM GOALS

Our long-term goals are (1) to determine the spatial and temporal scales of thin layers, (2) to identify the processes responsible for the formation, maintenance and dissipation of vertically thin layers, and (3) to develop the capability to predict thin layer formation and presence in the sea.

OBJECTIVES

The central focus of our research is to investigate: the spatial and temporal scales of thin layers, the relationship between physical processes (from the mesoscale to the microscale) and thin layers. With the overarching goal of ultimately determining how many physical variables are required to predict the occurrence of thin layers in the sea.

APPROACH

In March of 2007 we were awarded $112,842 for the fabrication of an autonomous profiler (the SeaHorse) for the detection of thin layers of phytoplankton in the coastal ocean. The SeaHorse (Figures 1, 2) makes use of wave energy to power extended, high-resolution profiling of water properties. The instrument is moored to the seafloor and is left to collect samples autonomously. High-resolution (< 2 cm) vertical profiles will be collected roughly once each hour between the bottom and the surface at an average ascent rate of 8 cm s^{-1}. Between profiles, the sensor package remains stationary at the bottom until the next sampling interval. A SeaBird SBE-19plus CTD on the profiler will measure temperature, salinity, and pressure. A SeaBird SBE-43 O_2 sensor will measure dissolved oxygen. A WET Labs Inc. WET Star Chlorophyll fluorometer on the profiler will measure chlorophyll fluorescence (an estimate of chlorophyll concentration). Finally, a WET Labs Inc. cs-25-66-p(red) C-Star transmissometer will measure beam transmittance. The unique aspect of this profiler is that it is equipped with 2-way telemetry. We will receive profiles of temperature, salinity, oxygen, chlorophyll concentration and beam transmittance throughout the water column (from the surface to the bottom) autonomously once each hour. This information will allow us to respond adaptively to layer-events in near-real time (i.e. within a 3 hour period, equip a small boat with additional acoustical, optical and physical instrumentation to sample the layer in high resolution). In addition the 2-way telemetry system allows us to adaptively change the sample rate of the SeaHorse profiler itself. For example, if we observe a layer at 10 m depth, we can instruct the profiler to maintain this depth and sample for as

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long as the layer persists. Finally, and perhaps the most basic advantage to real time telemetry is the simple assurance that the instrument is functional and recording reliable data.

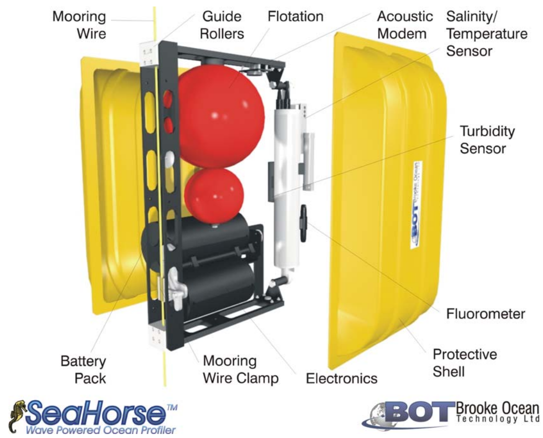

Figure 1. Schematic of the interior of the SeaHorse. Figure provided by Brooke Ocean Technology.

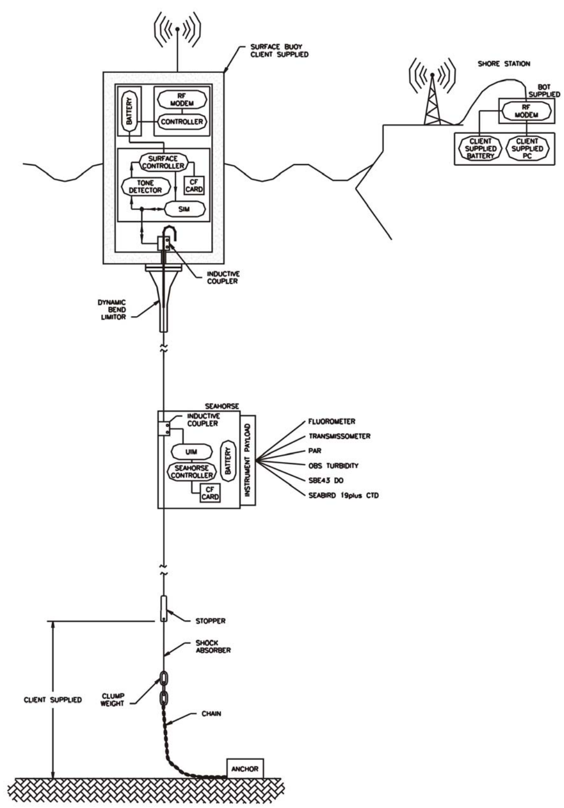

Figure 2. Schematics of the mooring design and telemetry link for SeaHorse Moored Profiler with telemetry. Figure provided by Brooke Ocean Technology.

WORK COMPLETED

Between March and April of 2007, we preformed considerable research on the autonomous profiler and instrument systems that sample from this platform. The fixed fee purchase order was issued on 13

August 2007 with a delivery date of 8 May 2008 to UH Manoa Department of Oceanography. Detailed descriptions of the equipment purchased and the cost of the items are listed in Table 1. Two price increases occurred from the time of the original quote for the profiler. First, the cost of the SeaHorse body itself increased from $28,932 to $32,247. Second the cost of the Custom buoy increased from $8,787 to $15,167. The cost increase for the SeaHorse is due to the increasing costs of materials and machined parts. The cost increase for the buoy arose because the original buoy cost was an estimate that came form BIO - the design was not complete when BIO quoted this project. Since that time BIO has constructed the buoy and fabrication and material costs were well above what was originally estimated. The PI will cover the cost difference ($9,695) with funds from a separate ONR grant. Approval for this expenditure has been approved by the program manager.

Table 1. Autonomous Profiler Specifications and Cost

System Component	Vendor	Actual Price
(1) Sea Horse • Plastic shell and frame measuring 37” x 24 “ x 14.75” • Depth rating 200 m • Ratcheting control system with integral pressure sensor • Data Logging Computer • Payload mounting bay capacity: 11 pounds (in water) • 102 Ahr battery • Mounting location for auxiliary battery pack	Brooke Ocean Technology Thornhill Drive Unit 11 Darmouth, Nova Scotia Canada B3B 1S1 50 Tel: (902) 468-2928 Fax: (902) 468-1388 Email: sales@brooke-ocean.com	**32,247.00**
(2) Instrumentation • SeaBird 19 plus:19plus SEACAT PROFILER pumped conductivity temperature, depth recorder (includes SBE 5M submersible pump, 8 MB memory, 2.5 meter data I/O cable, SEASOFT software, and complete documentation • 600 meter plastic housing • 350 meter strain gauge pressure sensor • 4 differential A/D channels, (0-5v inputs) • Substitute SBE 5T pump for SBE 5M pump • Wet-pluggable connectors (4) for data, pump and 4 differential A/D channels • WET Labs cs-25-660-p(red) C-Star transmissometer, 600 meter, 25 cm path • WET Labs WET Star Chlorophyll fluorometer, 600 meter, 75 mg or 150 mg range • SBE-43 Dissolved Oxygen sensor • BOT Integration fee	Sea-Bird Electronics Inc. 1808 136th Place NE Bellevue, Washington 98005 USA Tel: (425) 643-9866 Fax: (425) 643-9954 Email: seabird@seabird.com WET Labs Inc. 620 Applegate St. Philomath, Oregon 97370 USA Tel: (541) 929-5650 Fax: (541) 929-5277	**31,151.00**

(**3) Mooring Components** SeaHorse mooring wire: • Mooring length to accommodate at 20 meter water depth • Dual nicopress eyes with thimbles • stainless steel stoppers installed, both ends • Manufactured and pull tested with certificates	Brooke Ocean Technology Thornhill Drive Unit 11 Darmouth, Nova Scotia Canada B3B 1S1 50 Tel: (902) 468-2928 Fax: (902) 468-1388 Email: sales@brooke-ocean.com	**2,210.00**
(4) **Iridium Telemetry System:** • Seahorse Upgrade (UIM – Underwater Inductive Modem) • SIM (Surface Inductive Modem) • Built-in GPS antenna provides position data • Surface Controller/Shore Link • Shore Station Receiver/modem	Brooke Ocean Technology Thornhill Drive Unit 11 Darmouth, Nova Scotia Canada B3B 1S1 50 Tel: (902) 468-2928 Fax: (902) 468-1388 Email: sales@brooke-ocean.com	**36,929.00**
(5) Dynamic Bend Limiter • The dynamic bend limiter is used to protect the cable from bending fatigue. The bend limiter is equipped with a flange for bolting to the underside of the surface buoy	Brooke Ocean Technology Thornhill Drive Unit 11 Darmouth, Nova Scotia Canada B3B 1S1 50 Tel: (902) 468-2928 Fax: (902) 468-1388 Email: sales@brooke-ocean.com	**4,833.00**
(6) Custom Buoy • The custom buoy is designed specifically for use with the SeaHorse. All of the telemetry electronics are housed inside the buoy.	Brooke Ocean Technology Thornhill Drive Unit 11 Darmouth, Nova Scotia Canada B3B 1S1 50 Tel: (902) 468-2928 Fax: (902) 468-1388 Email: sales@brooke-ocean.com	**15,167.00**

RESULTS

The entire autonomous profiling system was purchased and has been received, including all necessary instrumentation. The SeaHorse autonomous profiler is now being prepared for its deployment in support of the ONR funded project: *"Importance of thin plankton layers in Hawaiian food web interactions: Research spanning from physical circulation to spinner dolphins"*. PIS Margaret Anne McManus and Kelly Benoit-Bird.

IMPACT/APPLICATIONS

Patchiness, or the variability in distribution of organisms over space and time, is one of the most important features of pelagic ecosystems. Patterns of biota in the ocean have significant impacts on population dynamics, trophic interactions, community organization and stability, as well as cycling of elements. More importantly for naval operations, these ubiquitous features have significant impacts on the use of acoustical and optical sensors in the ocean. For example, layers of zooplankton and

micronekton can actually provide a stronger signal to a depth sounder than the bottom. Phytoplankton layers produce a similar signal on downward looking optical instruments. These biological barriers to optical and acoustical instruments often occur simultaneously in shallow water habitats, making it extremely difficult to switch between optical and acoustical modes of detection. This masking of bottom characteristics and of other features near the seabed significantly changes the way operations occur in the nearshore environment. The ability to predict the presence and location of these biotic layers is necessary for making effective operational decisions in coastal environments.

RELATED PROJECTS

Related projects include: (1) D. Van Holliday & Charles F. Greenlaw (BAE Systems): “Layered Organization in the Coastal Ocean: Acoustical Data, Acquisition, Analyses and Synthesis”, (2) Percy L. Donaghay & James M. Sullivan (URI): “Layered Organization in the Coastal Ocean: 4-D Assessment of Thin Layer Structure, Dynamics and Impacts”, (3) Timothy J. Cowles (OSU): “Finescale Planktonic Vertical Structure: Horizontal Extent and the Controlling Physical Processes”, (4) Jan E.B. Rines (URI): “LOCO: Characterization of Phytoplankton in Thin Optical Layers”, (5) David M. Fratantoni & Nelson G. Hogg (WHOI): “The Physical Context for Thin Layers in the Coastal Ocean”, (6) Louis Goodman (U Mass Dartmouth): “AUV Turbulence Measurements in the LOCO Field Experiments”, and (7) Alfred K. Hanson (URI): “An Investigation of the Role of Nutrient Gradients in the Episodic Formation, Maintenance and Decay of Thin Plankton Layers in Coastal Waters”. Additional related projects include (8) Kelly Benoit-Bird (OSU) “Predator effects on dense zooplankton aggregations in the coastal ocean”, funded by the ONR Young Investigators Program, (9) Grieg Steward (UH) “Preliminary Investigations of Microbial Communities in Thin Layers of Plankton in Monterey Bay, California” funded by NOAA’s Undersea Research Program, and (10) Margaret Anne McManus, Kelly Benoit-Bird (OSU) “Importance of thin plankton layers in Hawaiian food web interactions: Research spanning from physical circulation to spinner dolphins”.